

*NHMF*L National High Magnetic Field Laboratory

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National High Magnetic Field Laboratory

1800 E. Paul Dirac Dr.
Tallahassee, Florida 32310

Phone:
850-644-0311

Fax:
850-644-8350

e-mail:
public-relations@
magnet.fsu.edu

Internet:
www.magnet.fsu.edu

EDITORS
Kathy Hedick
Jeff Simon

DESIGN PRODUCTION
Educational Media
Walter W. Thorner
Curtis Hendrickson
Laurie Anne Lusk

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INTRODUCTION

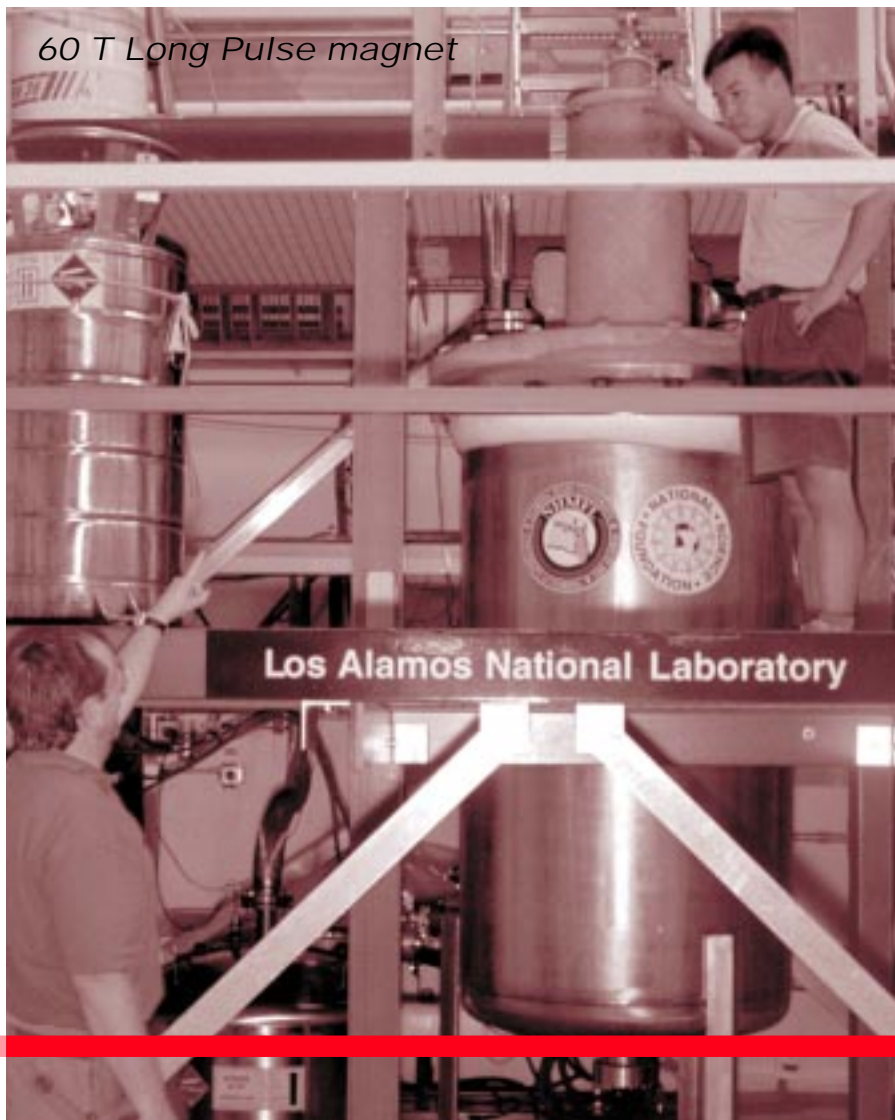
Volume 1 of the NHMFL's 1998 Annual Report is dedicated to the expanding research and science activities of the laboratory. This volume is published early in the year and contains user research reports and research-related sections and can be accessed on the Internet (<http://www.magnet.fsu.edu/publications/1998annualreport>) or by directly contacting the NHMFL. Volume 2 of the Annual Report addresses the progress of specific program areas of the laboratory and will be published in late summer.

The number of user research reports continues to grow — to 293 reports in this year's volume. These user research activities extend across diverse scientific disciplines, including biology, chemistry, geochemistry, materials engineering, magnet technology, cryogenics, and all aspects of condensed matter physics.

NHMFL Chief Scientist J. R. Schrieffer highlights some of the exciting research findings from 1998 in his introduction to Chapter 1, Research Reports.

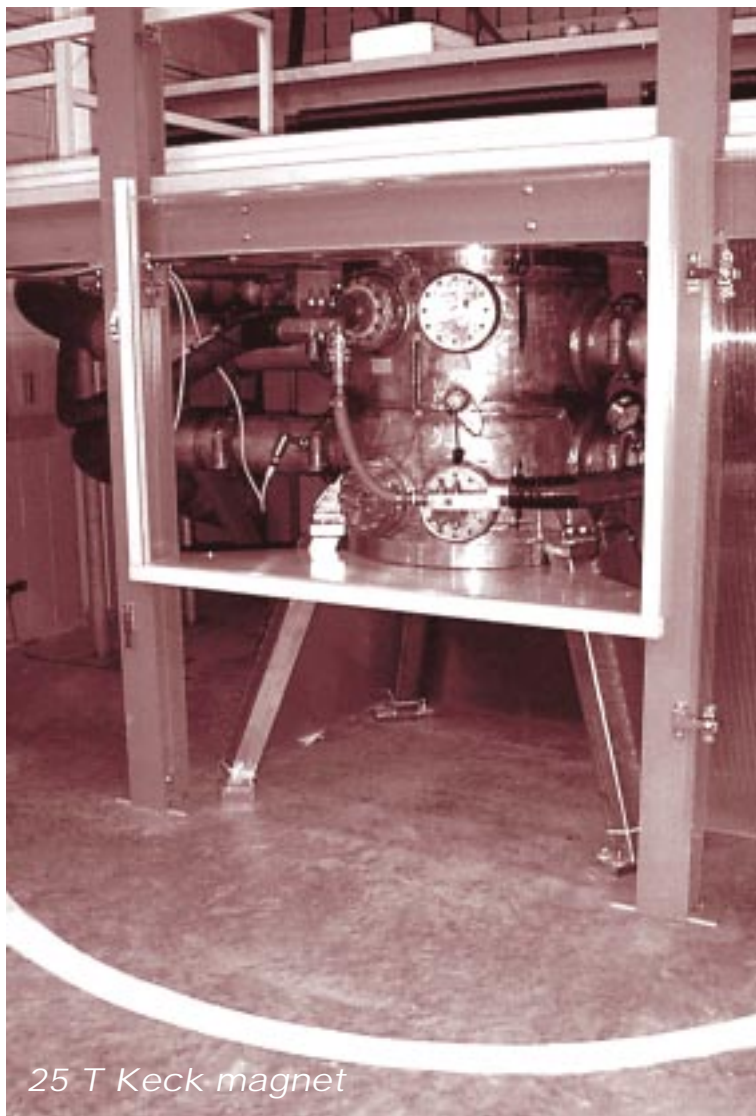
Several significant user enhancements were added to the NHMFL's repertoire of specialty magnets and instrumentation during 1998. At the NHMFL Pulsed Field Facility at Los Alamos, the 60 tesla (T) Long Pulse magnet was commissioned and opens exciting new avenues of high field exploration. The key features of the new magnet system are its long pulse duration and incredible flexibility, which allow users to tailor the magnetic-field pulse shape in

60 T Long Pulse magnet



response to the demands of the experiments. The 60 T magnet can be pulsed every hour and the magnetic-field pulse shape can be changed from pulse to pulse to accommodate experimentalists. Initial experiments show promising results in specific heat measurements, transport measurements in highly correlated electron systems, and photoluminescence spectra in semiconductors.

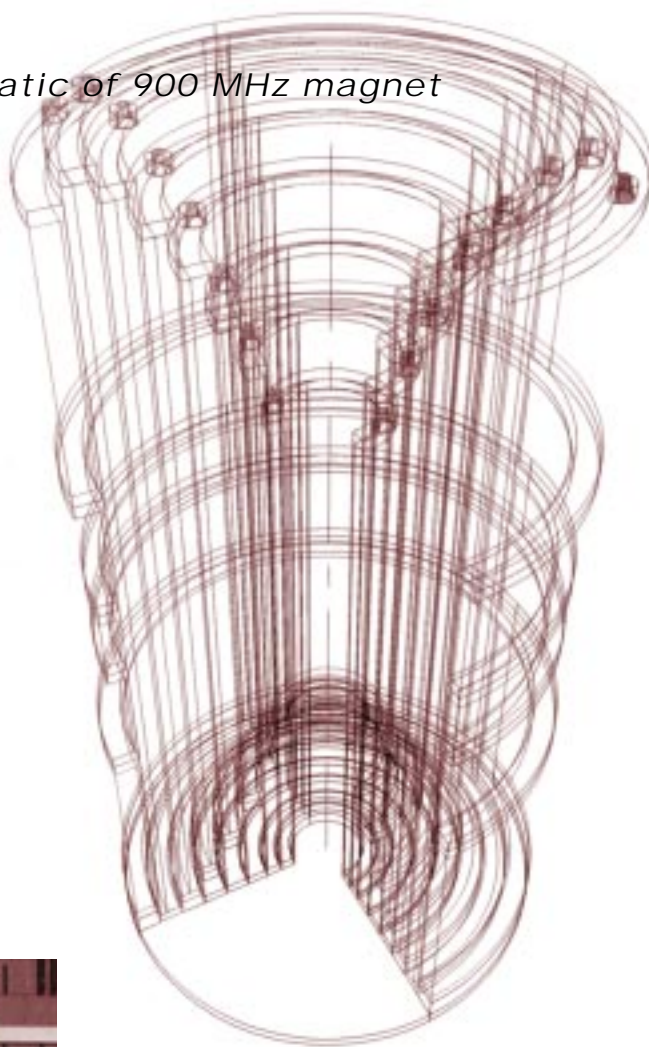
A one-of-a-kind direct current magnet for high homogeneity experiments was commissioned early in the year. Known as the “Keck” magnet because it is partially funded by a grant from the W. M. Keck Foundation, the magnet reaches 25 T in a 52 millimeter bore with field stability better than 1 part per million. The Keck magnet has opened interesting new opportunities in high field magnetic resonance, especially in electron magnetic resonance spectroscopy. Among the early experiments were studies of photosynthesis and motional dynamics. In photosynthesis, the increase in resolution allows for a precise determination of the electronic structure of the systems involved—information not available otherwise. Measurements at frequencies up to 670 GHz, possible only with this magnet, opened new means for examining the motions of complex fluids, for instance nitroxide spin-labeled molecules in the study of the glass transition in hydrocarbons.



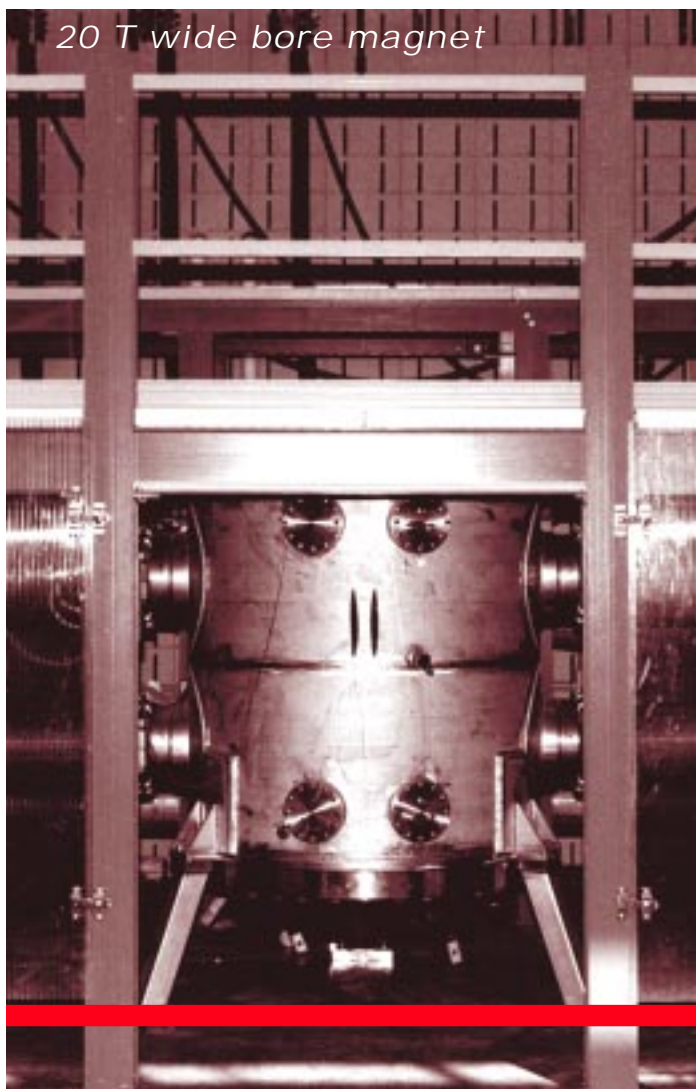
25 T Keck magnet

Schematic of 900 MHz magnet

In June, the 20 T, 195 millimeter warm bore magnet was commissioned. This unique magnet has been heavily used for acceptance testing of the superconducting wire for the 900 MHz magnet, as well as for materials processing studies such as high strength epoxies processed in high magnetic field. The 20 T wide bore has stimulated interest from new users to the laboratory, and experiments include ion cyclotron resonance, double axis rotation, and optics with light path perpendicular to the field direction.



20 T wide bore magnet



The NHMFL's ability to provide very low temperatures with very high magnetic fields expanded this year with the commissioning of a new Oxford portable, top-loading dilution refrigerator for resistive magnets. The field range available for low temperature experiments in DC fields has now increased to 33 T. The new Oxford dilution refrigerator will also be compatible with the 45 T Hybrid magnet when it becomes available. NHMFL staff has made several significant improvements to the apparatus by adding a micrometer drive to the string rotator that can be



Portable dilution refrigerator in 33 T magnet

moved through 360 degrees if the sample leads permit. A linear motion feedthrough system was developed for the dilution refrigerator that allows users to move their sample relative to the field center without having to remove the probe from the fridge.


The NHMFL's High B/T Facility at the University of Florida—the only such facility worldwide—has completed its first year of user operations with rave reviews. Some of the facility's first users were two of the 1998 Nobel

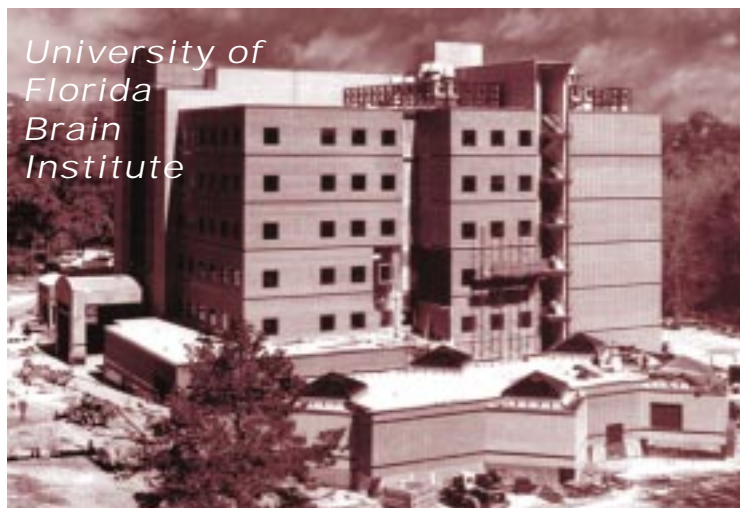
laureates in physics: Horst Störmer of Columbia University and Dan Tsui of Princeton University, studying the fractional quantum Hall effect. This unique facility provides users with the capability of carrying out studies that simultaneously reach very low temperatures (down to 0.4 mK) and high fields (20 T design). The facility is designed for studies of materials and systems that require high spin polarizations. This class of experiments includes transport on quantum heterostructures, quantum diffusion in highly polarized spin systems, and nuclear magnetism of various materials.



High B/T Facility

NHMFL In-House Research Program

The NHMFL's In-House Research Program is in its third year. The program supports research at all three sites that *utilizes* the NHMFL facilities to conduct high quality research at the forefront of science and engineering and *advances* the laboratory's facilities and its scientific and technical capabilities. The program encourages collaborations across the consortium institutions and with external users, and it supports bold but risky efforts that hold significant potential to extend the range of experiments. After three solicitations, a total of 135 proposals have been submitted, 70 have been sent to external review, and 32 have been funded. More information about the In-House Research Program can be found in Chapter 3, and research activities and reports supported by this program are designated in Chapter 1 with the  symbol.




The NHMFL MRI user program began to consolidate its efforts at the University of Florida Brain Institute, which was dedicated in Gainesville in the fall. A 12 T, 40 centimeter warm bore MRI system that will be part of this facility has been ordered along with a 750 MHz wide bore NMR system. Upon arrival, this new NHMFL MRI facility will become one of the preeminent centers for biological and bio-medical applications of magnetic resonance.

For those readers new to the NHMFL, the Tallahassee laboratory has developed world-record powered, or resistive, research magnets with fields up to 33 T. The uniqueness of the power supply combined with the world-class magnet development group have opened new frontiers in condensed matter physics by allowing nuclear magnetic resonance in resistive magnets in fields of 30 T. Unique pulsed field facilities are operated by the NHMFL at Los Alamos and magnetic resonance imaging and high B/T capabilities are located at the University of Florida. The NHMFL has initiated many collaborations with private companies to transfer its newly developed technologies and techniques to U.S. industry. The laboratory is funded by the National Science Foundation

and the State of Florida and is the only laboratory of its kind in the Western Hemisphere.



An Overview of the 1998 NHMFL Research Reports

1998 again showed an increased strength of the research programs in the laboratory. The number of projects increased to 293 compared to 256, 239, and 193 in the previous three years. There is increasing collaborative research between the external users and the in-house research staff, some of which is supported by the NHMFL In-House Research Program (see Chapter 3 for more information). Reports of research supported by this program are noted in this publication with the  symbol.

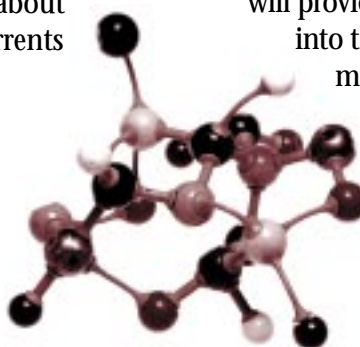
We are pleased to note that the research topics continue to evolve with time, with a large fraction of the material reporting on new topics. The largest number of projects are in order, magnetism and magnetic materials (36), molecular conductors (33), heavy fermions (31), semiconductors (31), biology (29), and basic superconductivity (28).

To highlight a few projects of broad interest, we have chosen a topic from each of the fifteen research areas of the laboratory as typical of the overall research program. Other projects of equal importance could have been chosen, as the reader will see.

Biology

One of the most fundamental processes in cellular communication is the controlled flow of ions across the membrane of a cell in response to external stimuli. In particular, virtually every activity in the brain or peripheral nervous system involves flows of ions across cells to create small electrical currents and changes in the voltage of the cell. The presence of such currents has been known and measured for years. Recently, electrophysiologists have developed techniques in which the currents from single ion channels can be directly measured, yielding a detailed understanding of the kinetics and activation profiles of these channels. Despite the wealth of physiological data, almost nothing is known about the underlying “black box” controlling these currents and the types of ions that can pass. Cross and coworkers are making significant advances in cracking open the “black box.” Over the last several years, the Cross laboratory has generated the highest resolution structure of a

membrane ion channel, gramicidin A. Using the detailed structural information from gramicidin A, the Cross group is now using high field NMR to make strong inroads toward explaining its function, including the mechanism of binding cations, the role of water in cation transport, and the observed specificity of cation selection. Results from the structural studies of the relatively simple gramicidin A will provide important insights into the functions of much more complicated channels whose detailed structures are not expected for some time. See Tian *et al.* page 35.



Chemistry

A most important challenge in analytical chemistry has been the development of experimental techniques with which one could determine the atomic composition and structure of complex chemical systems such as proteins and fossil fuels. In terms of mass resolving power, the progress in this area has been hampered by the lack of techniques with mass resolution above 1,000,000.

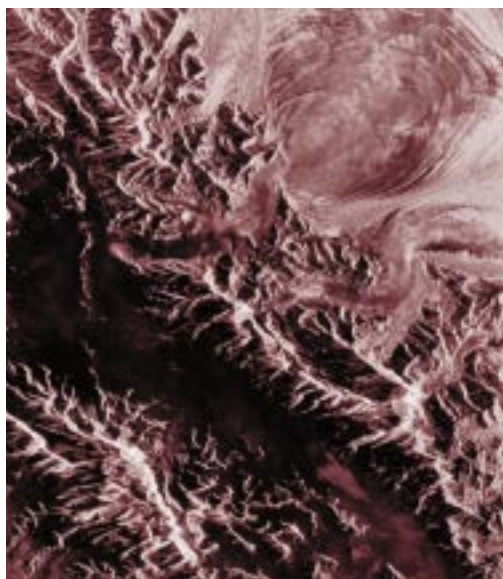
Recently, however, Marshall and coworkers have helped solve this problem by enhancing the mass spectral resolution to 8,000,000. This record-setting resolution enhancement has been made possible by the availability of a wide bore, 9.4 T magnet at the NHMFL. Utilizing this spectrometer, Marshall and his colleagues, Rogers, White, McIntosh, Andersen, and Hendrickson, were able to determine the structure of a tumor



suppressor protein and the difference in the structures of a system as complex as diesel fuel before and after sulfur-removal through chemical processing. Such a study would not have been possible without this added resolution. These studies thus open a whole new avenue for understanding chemical structure and reactivity patterns of complex biological and chemical systems with an accuracy as well as sensitivity unsurpassed by any other structural characterization methodology. See Marshall *et al.* page 50.

Geochemistry

New partition studies of Salters and Longhi predict larger fractionations of uranium and thorium by garnet than previous sets of coefficients. In addition, it is found that trace element partition coefficients for diopside and garnet are dependent on composition as well as pressure and temperature. Measurements of thorium and uranium isotopic composition in mid-ocean ridge basalts have indicated that melting beneath ridges starts at depths in excess of one hundred kilometers. Melting beneath ridges also requires an extremely low porosity matrix ($<0.1\%$) and a small degree of melting ($<0.1\%$) that is able to “escape” and ascend to the surface at a rate in excess of 30 centimeters per year. The inference of low porosities and small degrees of melting is strongly dependent on the partition coefficients between melt and matrix, especially the coefficients for the minerals diopside and garnet. Their new partition studies, which are the most appropriate yet for melting beneath mid-ocean ridges, enhance the fractionation of uranium and thorium by garnet and relax the requirement of extreme low porosities. Porosities of up to 1% can be allowed. In addition, the partition studies confirm that melting beneath ridges starts at depths in excess of 100 kilometers. The inferences from the partition studies are in agreement with experimental investigations of

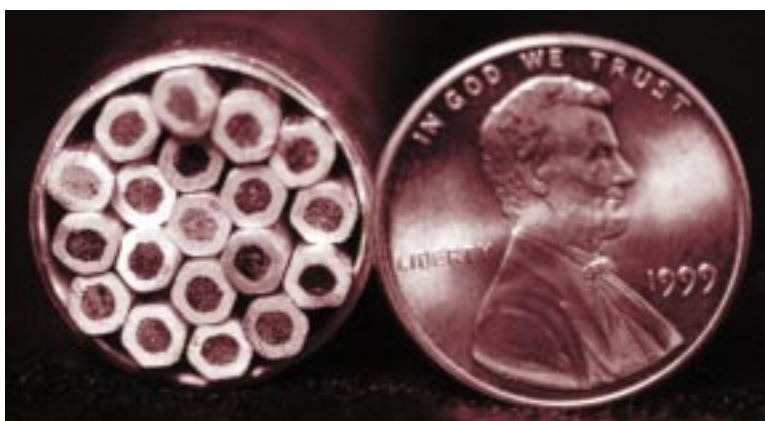


rheology and permeability of partially molten systems as well as with seismic tomography experiments at the East Pacific Rise. See Salters and Longhi, page 63.

Superconductivity — Basic

The study of fluctuation effects in high temperature superconductors can shed light on many of the important issues surrounding the nature of the superconducting state, including the effective dimensionality of the sample and the symmetry of the superconducting order parameter. With a well controlled theoretical model of the effect, one can also often extract important materials parameters such as the coherence length and the magnetic penetration depth. In many cases, however, the interpretation of the data is complicated, since there may be many different contributions to the property being measured. For instance, for the conductivity there is the “Aslamazov-Larkin” contribution as well as the “Maki-Thompson” term, and unraveling these competing effects is difficult. In addition, Varlamov and collaborators have discovered a “density of states” contribution, which was apparently overlooked in earlier theoretical treatments of these phenomena; experimental evidence for this effect in transport measurements has been indirect.

The recent high-field NMR measurements of the Pauli spin susceptibility and the spin-lattice relaxation rate in YBCO by Bachman *et al.* address exactly the issues raised above. For symmetry reasons there is no Aslamazov-Larkin contribution to the spin lattice relaxation rate, and the fluctuation effects are dominated by the density of states contribution, which simplifies the analysis. By comparing to a theoretical model that accounts for the effects of high magnetic fields (by summing over Landau levels) as well as Fermi liquid effects, the authors show that their data is only compatible with a superconducting state in which the order parameter has d-wave symmetry, and in which the fluctuations are effectively two dimensional. This work could also have implications for our understanding of the “pseudogap” phenomena in the underdoped cuprate superconductors, which may

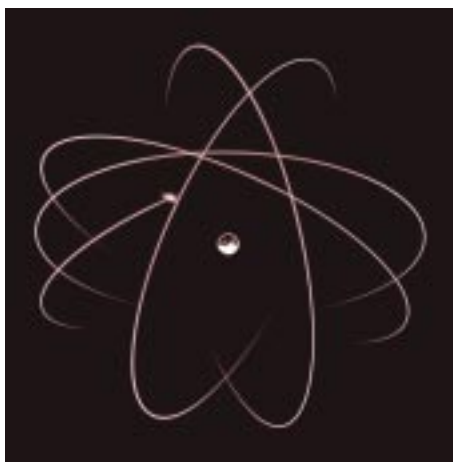
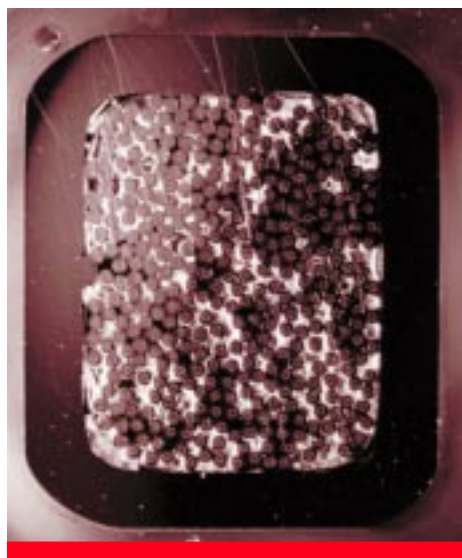


involve exactly the sort of density of states suppression that the authors have observed in these experiments. See Bachman *et al.* page 70.

Superconductivity — Applied

Since the discovery of high temperature superconductors over ten years ago, film and conductor applications in liquid nitrogen have been eagerly anticipated. One of the leading challenges, however, has been the development of a material with sufficient superconducting properties (T_c , H_{c2} , flux pinning, and intergrain connectivity) that can be produced as large area thin films or long-length conductors in contact with a suitable substrate or sheath.

The Hg-Ba-Ca-Cu-O has two superconducting phases that are potentially important technically: $\text{HgBa}_2\text{CaCu}_2\text{O}_x$ ($T_c = 125$ K) and $\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_y$ ($T_c = 134$ K). The



work reported by Roney, Schwartz, and Sastry is significant because it demonstrates that Hg-Ba-Ca-Cu-O superconductors can be synthesized in contact with

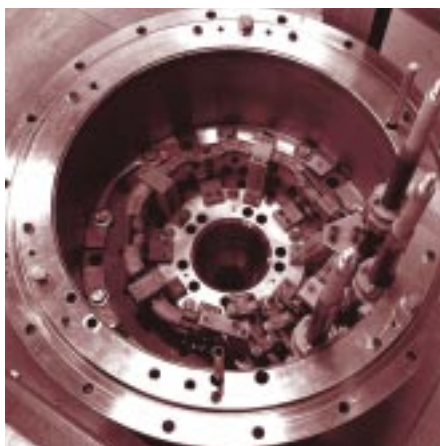
metallic substrates suitable for applications. Their work also maps out, for the first time, the stable phase fields when the superconductor is doped with Re, Pb, and Bi, which are important for chemical stability. These results show that large, well-aligned colonies of phase-pure superconducting grains (100s of microns in the a-b direction) can be grown directly from a solid-vapor reaction. The combination of large grain structures and compatibility with relevant substrates indicates that Hg-Ba-Ca-Cu-O has the potential to be the most important high temperature superconductor for film and magnet applications. See Roney *et al.* page 100.

Quantum Solids

One of the challenges in studies of the quantum solids formed by solid hydrogen has been to determine the nature of their order/disorder transitions in two dimensions (2D). Ortho hydrogen molecules are quantum rotors with angular momentum $J=1$, and as a result of intermolecular interactions are expected to order orientationally at extremely low temperatures. Because of the frustration of the interactions, new 2D locally ordered quadrupolar states were predicted. High sensitivity NMR studies have been used to show that long range order is obtained only for high ortho concentrations, and with the introduction of 32% disorder (by dilution with para hydrogen molecules, $J=0$) a new two dimensional spin-1 glass state has been observed. See Sullivan and Kim, pages 106 and 107.

Kondo Effect and Heavy Fermions

A leading experimental challenge in measurements at high magnetic field is that of obtaining data that is of direct use in theoretical models. This problem is particularly acute in pulsed high fields where the short duration of the pulse severely limits the kinds of measurements possible. The main experimental probe here in condensed matter has been electrical resistivity and, more recently, certain optical measurements. In the past year, a significant development has been heat capacity measurements by Jaime, Movshovich, Stewart, and Beyermann in the NHMFL's new 60 T Long Pulse magnet. They have succeeded in measuring the heat capacity of an interesting intermediate valence material YbInCu_4 that undergoes a field induced first-order phase transition. They also operated their experiment in a mode where the pulsed field was operated either in sweep mode or at a series of steps and found that thermal equilibrium could be achieved. The heat capacity allows a determination of entropy changes that are of crucial relevance to any theoretical model. This experimental innovation has now significantly widened our experimental phase space in pulsed magnetic fields. See Jaime *et al.* page 122.



electronic reconstruction below about 8 K that results in a number of highly unusual, magnetic field dependent transport phenomena. Several investigations at the NHMFL have made significant progress toward better

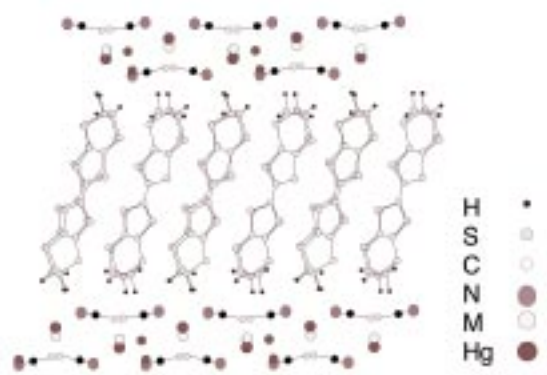
understanding the nature and the origin of the ground state of this remarkable system. Harrison and co-workers performed a number of transport measurements, including magnetization

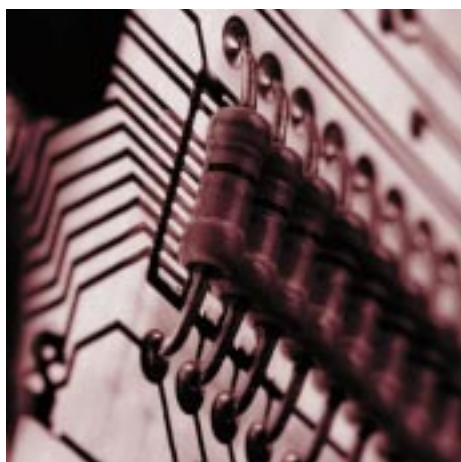
and angular dependent magnetoresistance measurements. Their work is well summarized in Harrison *et al.* (page 144) and Harrison (page 145).

In the first report a modified version of the original tight binding model

Molecular Conductors

The ground state of the organic conductor $\alpha\text{-(BEDT-TTF)}_2\text{KHg(SCN)}_4$ has remained one of the most hotly contested and elusive areas in molecular conductor physics for nearly 10 years. This arises from the coexistence of open and closed orbits in its quasi-two dimensional Fermi surface. Here the low temperature ground state takes on a complex





Fermi surface is proposed that has been adjusted to take into account all known peculiarities of the transport measurements, including the observed quantum oscillation frequencies, the appearance of new open-orbit like behavior in the ground state, and magnetic breakdown phenomena. In the second report, the possibility of a charge density wave ground state, rather than a spin density wave state, is discussed.

Fortune *et al.* (page 139) carried out the first specific heat measurement through the so-called “kink field” transition around 22.5 T and up to 33 T in α -(BEDT-TTF)₂KHg(SCN)₄. The first order nature of this transition was reported, and other hysteretic anomalies were discovered above the transition.

The microscopic nature of the low temperature ground state of α -(BEDT-TTF)₂KHg(SCN)₄ was addressed by ¹³C NMR to 28.8 T by Kuhns *et al.* (page 155). The ¹³C

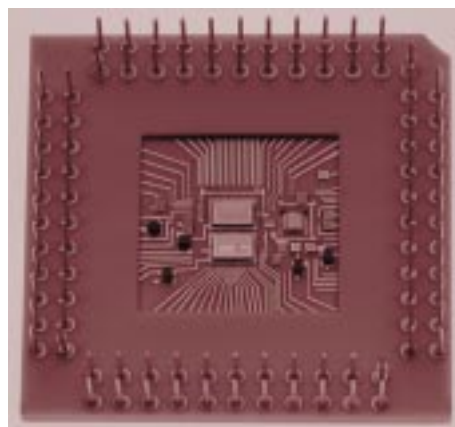
substitution sits at the center of the molecular orbital and is therefore sensitive to any magnetic or electronic changes at the transition to the ground state. The results of the NMR spectra were consistent with a non-magnetic ground state, and the behavior of the relaxation rate indicated that the ground state remains at low temperature well above the first order “kink transition” at 22.5 T.

The work of these three experimental groups therefore suggests that the ground state of α -(BEDT-TTF)₂KHg(SCN)₄ may be non-magnetic (perhaps CDW); and may involve low temperature sub-phases separated by a first order phase boundary near 22.5 T.

Of further note is the increase in high field nuclear magnetic resonance studies of various broken symmetry ground state systems: SDW (Brown *et al.* page 136, and Clark *et al.* page 138), CDW (Kuhns *et al.* page 155), and even polymeric systems (Clark *et al.* page 137). In particular, the importance of high fields is nicely shown in the work of Brown *et al.* where the ¹³C line of the Spin-Peierls (S-P) system (TMTTF)₂PF₆ is measured from 17 T to 23 T. The breaking of the S-P state by high magnetic field, and the onset of localized magnetic moments is made dramatically clear in the field dependence of the line-width.

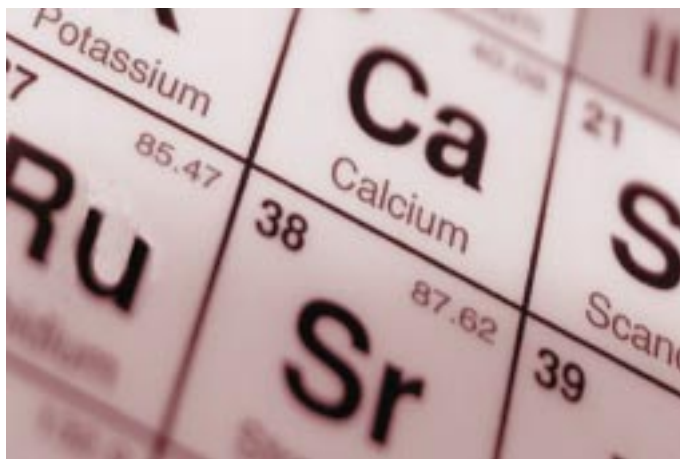
Semiconductors

Among the wide range of semiconductor experiments performed at the NHMFL, we call particular attention to two reports resulting from new capabilities at



the NHMFL that have enabled the extension of research in two dimensional electron systems. The first report, by Pan *et al.*, summarizes experiments on the fractional quantum Hall effect (FQHE) in a high quality GaAs/Ga_{1-x}Al_xAs sample at extremely low temperatures (4 mK) in magnetic fields up to 15 T. The observation of a fully developed FQHE state at $\nu = 5/2$ featuring vanishing resistivity R_{xy} , relied on the availability of extremely low temperatures produced by the nuclear demagnetization refrigerator at the NHMFL High B/T Facility at the University of Florida. Substantial high magnetic field research supports the existence of a degenerate system of composite fermions at half integer filling in the lowest Landau level. The results of Pan *et al.* indicate that the ground state at half integer filling in the second Landau level is instead a two-component fractional quantum Hall state. See Pan *et al.* page 188.

The second report, Crooker *et al.*, describes photoluminescence measurements on recently available magnetic semiconductor quantum wells using the newly-commissioned 60 T Long Pulse magnet at the Los Alamos site of the NHMFL. Due to the presence of Mn ions in the quantum well, the two-dimensional electron system becomes highly spin polarized even at low magnetic fields. In this regime, Zeeman shifts of the photoluminescence peaks do not follow the anticipated Brillouin-function dependence on magnetic field and instead show unexpected and as yet unexplained features near integer filling of the spin-polarized Landau levels. See Crooker *et al.* page 172.



Magnetism and Magnetic Materials

One of the most challenging problems in condensed matter physics is the nature of the transition from the Mott insulator phase in which electrons are localized on atomic sites to a strongly correlated metal phase. In the former, one generally observes long range ferromagnetic order, while in the later one has strong antiferromagnetic spin fluctuations that interact with the conduction electrons. One important class of these materials is the ruthenates, which are layered materials. Studies by Cao *et al.* (page 202) were carried out on the calcium-based series, Ca₂RuO₄, Ca₃Ru₂O₇, and CaRuO₃. They have discovered a very high metal-insulator temperature $T_M=357$ K in Ca₂RuO₄, but unlike other materials, it does not undergo magnetic order. The transition appears to be due to a lattice phase transition. This is an example of the interplay of several coupled phase transitions that occur in these materials. The temperature dependence of the resistivity is not of the activated form, but rather fits a hopping model in which Coulomb interactions play a strong role.

Other Condensed Matter

Three reports this year independently show that there are novel phenomena yet to be found when elemental metal crystals are exposed to high magnetic fields. In the first of these (Marchenkov, Stalcup, Brooks, Weber, Levit, and Kaufman), the magnetic field dependence of electron-dislocation scattering in ultrapure tungsten and molybdenum crystals is studied. The temperature and angular dependence of the transverse magnetoresistivity confirms the existence of a dislocation breakdown mechanism in which small angle electron-dislocation scattering leads to a transfer of conduction electrons between different Fermi surface sheets. Unexpectedly high anisotropies in the magnetoresistivity are attributed to this mechanism. See Marchenkov *et al.* page 234.

In a second paper on electronic transport in similar samples (Marchenkov, Hall, Stalcup and Brooks) the skipping

orbits of electrons scattered at the metal surface are found to give rise to an additional magnetic moment together with voltages that reverse sign with magnetic field. These two interesting reports are significant because they highlight unexpected behavior that could be relevant to other experiments done at high fields on ultra-pure metals. See Marchenkov *et al.* page 233.

The third report in this category (Molodov, Gottstein, Heringhaus, Shvindlerman) shows that grain boundary energies can be directly measured from the magnetic field induced grain boundary distortion in bismuth bicrystals. The sample is annealed in high fields and the curvature of the grain boundary along a 5 mm length is directly measured. The result is significant because it suggests novel ways in which magnetic fields can be used for the processing of materials having strong magnetic anisotropies. See Molodov *et al.* page 235.

Magnetic Resonance Techniques

Crucial components of magnetic resonance technology are the homogeneous, high magnetic field and the resonator for coupling to the sample. Advances in these areas allow improved sensitivity and resolution and applications to hitherto inaccessible problems. In 1998, researchers at the NHMFL made significant advances in both of these technologies.



Using micro-solenoidal radio-frequency resonant coils and the 600 MHz microimaging NMR system in Tallahassee, Blackband and coworkers (page 241) have obtained the first spatially localized proton NMR spectra from subregions of a single cell and the first sodium NMR images of a single cell. These measurements hold promise not

only for understanding the cellular basis of contrast in magnetic resonance imaging (MRI) but also for understanding details of cellular organization and metabolism. Soghomonian and Cross (page 253) report field maps obtained by nuclear magnetic resonance for the 25 T, resistive Keck magnet; further improvements in spatial and temporal homogeneity may allow extremely high sensitivity NMR. Work in collaboration with Conductus and Bruker (page 241) has produced high sensitivity, superconducting radio-frequency coils for NMR spectroscopy at fields as high as 25 T. Mareci and coworkers (page 247) report continued improvements in implanted radio-frequency coils for *in-vivo* NMR spectroscopy of spinal cord.

In addition, the NMR and EMR groups have made significant improvements in observing solid state molecular structure and dynamics by spectroscopic methods. Examples are the reports by Gan (page 246) on high resolution dipolar spectroscopy, Fu *et al.* (page 245) on temperature jump methods, and Smith and Randall (page 252) on NMR imaging (STRAFI) of solids.

Engineering Materials

The construction of a high field magnet is limited by the available choice of conductor, insulation, and reinforcement materials. The commercially available insulation and reinforcement materials currently appear to satisfy the design requirements for a 100 T pulsed magnet. The conductor requires high mechanical strength (>1 GPa), high conductivity (>75%IACS), good elongation, forgiving plastic behavior, long fatigue life (>10,000 discharges), high resistivity ratio (ratio of resistivity at 77 K and 295 K), and suitable wire cross section and length. No such conductor is commercially available yet. The research effort in this field at the NHMFL encompasses the choosing of the elements to make a conductor, the



selection of a suitable fabrication route, and characterization of the mechanical/electrical properties and microstructure of the materials. The chief challenge to be overcome is to evolve a new material with high electrical conductivity and strength simultaneously because factors responsible for strength increase often lead to decrease of conductivity. The main goal is to develop a new conductor for the construction of a 100 T pulse magnet. See Brandao *et al.* pages 257 and 258.

Magnet Technology

As superconducting magnets increase in size and field strength, their performance limitations become increasingly related to the issue of stress containment. It is fortunate that stainless steel has many characteristics that make it quite suitable for application in superconducting magnet technology, including high modulus, strength at low temperature (a thermal contraction that closely approximates that of copper) and a high melting point important for coil processing. But some magnet applications, including NMR magnets, place very high demands on field uniformity and the ability to predict field uniformity in a magnet construction. The permeability of steel and the potential for the steel to contribute a large unwanted field component cannot be ignored. The wide application of steel in cryogenic environments has led to a broad data base of steel properties for superconducting magnet applications. The available data on steel permeability, including the influence of processing and operation of the steel in a given application, is still rather limited. For NMR magnet design requirements, Swenson *et al.* examined aspects of steel permeability at low temperature, including the possibility of forming low permeability welds and the

influence of strain at low temperature. Briefly, they found that the modern highly doped weld rods now available do an excellent job of suppressing ferrite formation in the heat effected zone, to the extent that welded structures may be incorporated in NMR magnet systems. Additionally, at the level of strain typically seen in the reinforcement, the permeability is not enhanced under cyclic loading in type 316L stainless steel. See Swenson *et al.* pages 265 and 266.

Cryogenics

The four reports in Cryogenics are all directed toward improving our understanding of He II (superfluid helium) heat and mass transfer processes for applications to superconducting magnet cooling. Of particular interest are two reports on He II/vapor two-phase flow studies, which involve the combined processes of heat and mass transfer in co-existing liquid and vapor helium at temperatures around 2 K. Mass exchange is allowed to occur between the two phases. A finite difference numerical model accurately describes experimental results on a horizontal channel. Although results have been previously reported on two-phase He II/vapor, the current work represents the first use of a model that contains all the unique transport properties of He II to describe these processes. See Panek *et al.* pages 268 and 269.

The other two reports on He II cryogenics involve single phase He II at very high Reynolds number ($Re \approx 10^7$). One of these concerns a model developed to describe the temperature profile in pipe flow. This semi-analytic model can predict the effect of the Joule-Thomson expansion and He II counterflow. The last report involves the measurements of the drag coefficient on a sphere in He II. This work is particularly significant for it shows that He II displays a drag crisis at the critical Reynolds number, $Re \approx 10^5$, similar to that of classical fluids. Above the drag crisis, the apparent temperature dependence to the drag coefficient may suggest some superfluid effects. See Baudouy *et al.* page 268, and Smith *et al.* page 270.